Assessment of Coracoclavicular Ligament Healing on MRI After Arthroscopic TightRope Fixation for Acute Acromioclavicular Joint Dislocation

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Background: Arthroscopic-assisted fixation of acute high-grade acromioclavicular (AC) joint dislocation has gained popularity in the last decade. Coracoclavicular (CC) fixation using the TightRope device is a less invasive technique.

Purpose: To investigate CC ligament healing and functional outcomes after arthroscopic fixation using the TightRope device for acute AC joint disruption.

Study Design: Case series; Level of evidence, 4.

Methods: The study retrospectively analyzed the data of patients admitted for arthroscopic surgical treatment of acute AC joint injury using a single TightRope device. The data collection commenced in October 2021. The Constant-Murley (CM) score and University of California, Los Angeles (UCLA) shoulder score were used for functional evaluation. The CC distance (CCD) was measured on plain radiographs, whereas healing of the CC ligament was evaluated on magnetic resonance imaging (MRI). Statistical analyses were conducted with the Mann-Whitney *U* test, independent *t* test, or paired *t* test, as appropriate.

Results: The analysis included 33 patients with a mean age of 37.7 years (range, 24-49 years) and a minimum follow-up of 24 months. Significant preoperative to postoperative increases were noted in both the CM and UCLA scores (from 34.1 ± 7.6 to 93.3 ± 3.6 and from 8.7 ± 2.1 to 32.9 ± 1.7, respectively; $P < .0001$ for both). The CCD decreased from 21.8 ± 3.02 mm preoperatively to 10.6 ± 1.2 mm postoperatively ($P < .0001$). All patients displayed CC ligament healing on MRI. Two patients with superficial infection and 1 case of partial reduction loss were confirmed at the end of this study.

Conclusion: The arthroscopic TightRope technique was found to be a reliable and less invasive method of fixation for acute AC joint disruptions. The CC ligament healed adequately based on MRI evaluation, and the patients regained their preinjury activities, with favorable functional outcomes and minor comorbidities.

Keywords: AC joint; arthroscopic fixation; TightRope device; MRI

Acute acromioclavicular (AC) joint dislocation is a common shoulder injury, representing 12% of all traumatic shoulder events and being about 20% more common in men than in women.[7,19,35] The mechanisms of injury are either a direct shoulder collision with the floor and during sports or an indirect injury from falling on an outstretched hand, with direct trauma being the most common.[24] Rockwood[30] classified AC joint injuries into 6 categories: type 1, AC ligament sprain; type 2, AC ligament disruption and coracoclavicular (CC) ligament sprain; type 3, torn AC and CC ligaments with AC joint dislocation; type 4, AC joint dislocation with posterior displacement of the distal clavicle; type 5, AC joint dislocation with severe superior displacement of the distal clavicle (>100%); and type 6, distal clavicle displaced inferior to the acromion. Type 3 injuries were further subdivided by the International Society of

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Final revision submitted March 1, 2023; accepted April 13, 2023.

The authors have declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from Zagazig University (ref No. 9781/15-09-2021).

The Orthopaedic Journal of Sports Medicine, 11(10), 23259671231185749
DOI: 10.1177/23259671231185749

Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine into types 3A (horizontal-stable), and 3B (horizontal-unstable).[4]

Most orthopaedic surgeons recommend nonoperative modalities for Rockwood type 1 and type 2 injuries, whereas surgical intervention is reserved for high-grade disruptions (types 4-6).[2,16,28,31,32,34,37] Management of type 3 dislocation is contentious in the published literature, but there is a consensus that surgical treatment is preferred because it has better clinical outcomes compared with nonsurgical measures in young, active patients with high demands.[15]

Numerous surgical methods have been used for open surgical fixation of AC joint dislocation, including hook plates, Kirschner wires, Bosworth CC screws, distal clavicle resection, and the Weaver-Dunn technique, with no reported superiority of any technique.[12,17,33] Hardware-related complications, unsightly scars, infection, wound dehiscence, and a second operation for implant removal are the main concerns with open fixation.[23,29] The primary advantage of the arthroscopic technique is that it avoids the complications associated with open surgery.[20] Arthroscopic-assisted CC fixation using the TightRope device (Arthrex) is a less invasive technique, with comparable functional results and fewer complications than traditional open surgery.[6,14] Several studies have reported the clinical outcomes of arthroscopic CC fixation using double cortical buttons,[11,32,39] but the healing of CC ligaments has not been widely investigated.

The purpose of this study was to evaluate the clinical results and CC ligament healing after arthroscopic fixation using the TightRope implant for acute AC joint disruption. The hypothesis was that arthroscopic TightRope fixation of acute AC joint dislocations would provide adequate CC ligament healing and good clinical results.

METHODS

After receiving informed consent, we retrospectively enrolled patients with acute AC joint dislocation who underwent surgery between July 2017 and May 2019 at 2 university hospitals. All included patients underwent arthroscopic assisted fixation using the TightRope device via the single-tunnel technique. The study eligibility criteria were acute AC joint dislocations grades 4 through 6, with grade 3 injuries in athletes and those who had overhead activities or heavy manual work. Excluded were injuries lasting >3 weeks, Rockwood type 1 and 2 injuries, type 3 lesions in sedentary patients not engaged in overhead or sporting activities, concomitant rotator cuff or superior labrum anterior-posterior injuries, and patients with incomplete medical records.

Of 39 patients initially evaluated, 6 patients were excluded (3 patients with an accompanying superior labrum anterior-posterior lesion, 1 patient with a rotator cuff tear, and 2 patients with insufficient medical data); thus, our study involved 33 patients. The characteristics of the included patients are listed in Table 1.

TABLE 1
Characteristics of the Study Group (N = 33)[a]

Characteristic	Value
Age, y	37.7 ± 7.1 (24-49)
Sex	
Male	29 (87.9)
Female	4 (12.1)
Side	
Dominant	21 (63.6)
Nondominant	2 (36.4)
Rockwood type	
Type 3	9 (27.3)
Type 5	24 (72.7)
Injury mechanism	
Traffic collision	19 (57.6)
Fall (from height and down stairs)	10 (30.3)
Sports	4 (12.1)

[a]Data are shown as mean± SD (range) or n (%).

Surgical Technique

All procedures were performed under general anesthesia by 2 qualified shoulder arthroscopy surgeons (M.F.E. and F.S.F.) with intravenous administration of 1 g of cefuroxime at 1 hour before surgery. The patients were seated in the beach-chair position. Three portals were used for this technique. First, the classic posterior portal (2 cm distal and medial to the posterolateral corner of the acromion process) was used for glenohumeral joint exploration. The anterosuperior and anteroinferior portals were created using a spinal needle with an outside-in technique. The rotator interval was released entirely, revealing the undersurface of the coracoid process with a radiofrequency ablator. The arthroscope was moved into the anterosuperior portal for better viewing of the coracoid base. An aiming device was centered underneath the coracoid process via the anteroinferior portal, and a guide pin was drilled from the center of the upper surface of the clavicle to the inferior surface of the coracoid through a 1.5-cm incision at a point located 2.5 to 3 cm medial to the AC joint, without violation of the deltotrapezial fascia (Figure 1, A and B). A 4.5-mm cannulated drill bit was passed over the guide pin, creating a tunnel through the clavicle and the coracoid. A flexible nitinol wire was threaded through the drill bit and retrieved from the anteroinferior portal. The traction suture of the TightRope device was passed through the eyelet of the nitinol wire to deliver one cortical button over the clavicle while the other button settled below the coracoid (Figure 1C). The joint was reduced by manual downward pressure on the lateral end of the clavicle along with axial upward elevation of the arm. After tensioning of the TightRope sutures, the final position of the AC joint was affirmed using a mobile C-arm machine. The deltotrapezial fascia, subcutaneous fascia, and skin were closed in layers.

Postoperative Management and Follow-up

A prophylactic antibiotic was prescribed postoperatively for 24 hours for all patients to minimize the risk of

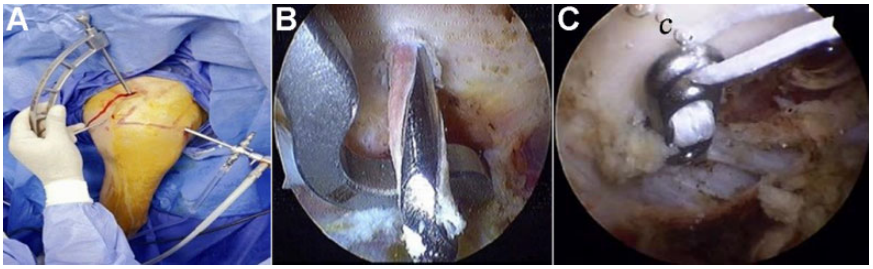

Figure 1. (A) The left shoulder joint was viewed from the posterior portal, and a drill pin was passed through the guide system (B) from the clavicle to the base of the coracoid process. (C) The cortical button was retrieved from beneath the coracoid, *c*.

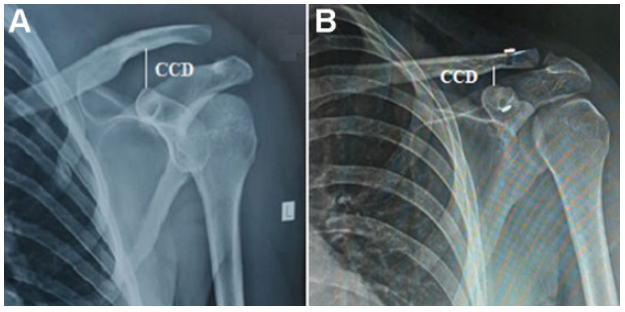

Figure 2. Zanca shoulder anteroposterior radiographs in 2 patients demonstrate the difference in the coracoclavicular distance (CCD) (A) before and (B) after surgery.

peri-implant infection. The sutures were removed after 14 days, and the arm was held in a sling for 6 weeks. Passive elbow and shoulder motions began immediately after surgery. Active shoulder motions were permitted after 6 weeks. Weightlifting and competitive sports activities were deferred for 12 weeks.

At the last follow-up, the Constant-Murley (CM) score,[9] University of California, Los Angeles (UCLA) shoulder score,[1] and shoulder forward elevation were recorded for functional evaluation. An orthopaedic staff member (M.S.E.) estimated the radiographic CC distance (CCD) as the shortest distance between the highest point of the upper cortex of the coracoid and the lower border of the clavicle on radiographs for both shoulders (anteroposterior view with 10° cephalic tilt) (Figure 2).

At 12 months postoperatively, patients underwent 1.5-T magnetic resonance imaging (MRI) (Achieva; Philips) to assess healing of the CC ligaments in the sagittal oblique, coronal oblique, and axial planes (scan geometry, $\leq 0.4 \times 0.4$ mm in-plane spatial resolution; field of vision, 120-160 mm; slice thickness, 3 mm). Automatic shimming and manual shimming were used to reduce the metallic artifacts. The T2-weighted sequences were considered more reliable because they showed fewer artifacts. The quality of healing on MRI was classified into 4 categories according to Ihara et al[18]: grade 1 demonstrates a thick band ligament with a uniformly low signal intensity; grade 2 has the same features as grade 1 but with a few high-signal intensity points; grade 3 is a low-signal thin band with high-signal mass; and grade 4 is a thin band of undistinguished signal.

TABLE 2
Clinical and Radiological Outcomes[a]

	Preoperative	Postoperative	*P*
UCLA score	8.7 ± 2.1 (7.9-9.4)	32.9 ± 1.7 (32.2-33.5)	<.00001
CM score	34.1 ± 7.6 (31.4-36.7)	93.3 ± 3.6 (92.02-94.5)	<.00001
CCD, mm	21.8 ± 3.02 (20.7-22.8)	10.6 ± 1.2 (10.1-11.02)	<.00001

[a]Data are displayed as mean ± SD (95% CI). All pre- to postoperative differences were statistically significantly ($P < .05$). CCD, coracoclavicular distance; CM, Constant-Murley; UCLA, University of California, Los Angeles.

Grades 1 and 2 correspond to successful healing and sufficient stability. The MRI evaluations were conducted by 2 orthopaedic surgeons (U.G.A. and L.S.).

Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) (Version 16; IBM). Before statistical testing, the distribution of data was validated using the Kolmogorov-Smirnov test. The study variables were recorded as means and standard deviations or as absolute values with percentages, and 95% CIs were calculated for the outcome values. The *t* test for paired means was used to compare the preoperative and postoperative CM score, UCLA score, and CCD, whereas the Mann-Whitney *U* test and independent *t* test were used to compare the shoulder elevation and CCD at final follow-up with the unaffected side. The Kendall τ correlation coefficient was implemented to evaluate interobserver reliability, with the level of agreement ranked as poor (<0.20), fair (0.21-0.40), moderate (0.41-0.60), good (0.61-0.80), or excellent (0.81-1.00). Results with $P < .05$ were presumed statistically significant for all tests.

RESULTS

For the 33 study patients, the mean time between injury and surgery was 5.3 ± 2.9 days, and the mean operative time was 56.2 ± 8.3 minutes. The mean follow-up time was 29.6 ± 3.2 months.

Table 2 summarizes the clinical and radiological outcomes. A significant improvement was seen in the CM

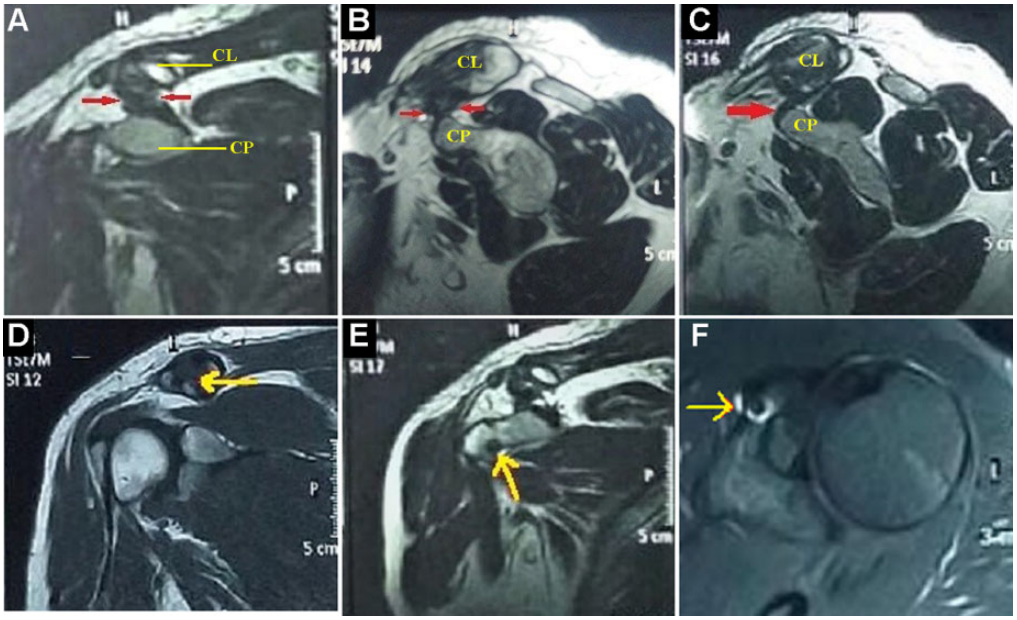

Figure 3. MRI T2-weighted sequences showing grade 2 coracoclavicular ligament healing (red arrows) in the (A) coronal and (B and C) sagittal cuts. The artifact shadows of the cortical buttons appear on the upper surface of the clavicle in the (D) coronal cut and beneath the coracoid in the (E) coronal and (F) axial cuts (yellow arrows). CL, clavicle; CP, coracoid process.

score, from 34.1 ± 7.6 preoperatively to 93.3 ± 3.6 at the final follow-up ($P < .00001$). The UCLA score also improved significantly, from 8.7 ± 2.1 preoperatively to 32.9 ± 1.7 postoperatively ($P < .00001$). The CCD was reduced significantly from 21.8 ± 3.02 mm preoperatively to 10.6 ± 1.2 mm postoperatively ($P < .00001$), with no significant difference compared with the contralateral side (10.6 ± 1.2 mm) ($P = .06$). At the final follow-up, the mean forward shoulder elevation was 171.2° ± 4.8°, with a statistically significant variation from the unaffected side (174.1° ± 3.6°) ($P = .02$).

All patients attained CC ligament healing scars at 1-year follow-up (Figure 3). Regarding CC ligament healing on MRI, 1 reviewer reported 11 ligaments with grade 1 and 22 ligaments with grade 2 healing, whereas the other reviewer reported 8 grade 1, 24 grade 2, and 1 grade 3 ligament healing (81.8% agreement between reviewers). The Kendall τ correlation coefficient for interobserver reliability was 0.63 ($P = .0003$), indicating good agreement.

The mean time to resume previous occupation was 11.5 ± 1.6 weeks. Three minor complications occurred in our study: 1 patient had postoperative partial loss of reduction of 3 mm without pain or limitation of shoulder elevation (Figure 4), and 2 patients had superficial surgical site infection that was healed with daily dressing.

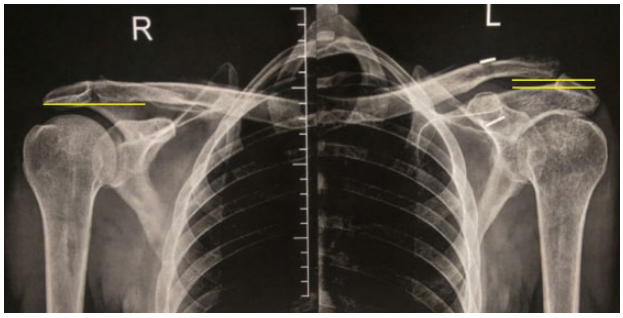

Figure 4. Bilateral shoulder radiographs (Zanca view) demonstrating partial subluxation of the acromioclavicular joint on the operated side (left) compared to the unaffected side (right) (yellow lines).

DISCUSSION

Our study revealed adequate CC ligament healing on MRI at a minimum 2-year follow-up after arthroscopic fixation of acute AC joint lesions. There was statistically significant improvement in the CM and UCLA scores postoperatively compared with preoperatively ($P < .0001$ for both), and all patients had achieved unrestricted manual activities at the final follow-up.

The most common injury mechanism in our study was traffic accidents (57.5%). However, in their studies of patients with acute AC dislocation, Çarkçı et al[8] and Olivos-Meza et al[26] stated that most injuries were sports-related (41.7% and 40.3%, respectively). We found Rockwood type 5 injuries in 24 (72.7%) patients, with a male predominance of 87.8%, which matches the findings of the previous studies.[8,26] Olivos-Meza et al[26] found that patients in whom reduction was preserved had a shorter interval to surgery than those with failed reduction ($t = 14.6$; $P = .0001$), and the investigators advocated for early surgical intervention (before 3 weeks) to facilitate AC joint reduction. Our study disclosed a mean time elapsed before surgery of 5.3 days (range, 2-14 days), which was close to

the values of Çarkçı et al[8] (6.7 days) and Olivos-Meza et al[26] (12.8 days).

The optimal method of fixation for acute AC joint injuries should provide sufficient strength and preserve the CCD to give the CC ligaments and the surrounding soft tissues the chance to heal.[21] Satisfactory postoperative outcomes have been reported since the arthroscopic TightRope fixation method for treating AC joint dislocation was first outlined. The TightRope device consists of 2 titanium cortical buttons and No. 5 FiberWire with an adjustable-loop design that permits tensioning between the buttons. The TightRope device is distinguished from others in that it is low-profile and does not require another surgical procedure for implant extraction.[3] A biomechanical study estimated the ultimate strength of the TightRope system, which was greater than that of the native CC ligaments (1400 vs 700 N, respectively).[10] Our patients were operated on via the single-tunnel technique to prevent iatrogenic coracoid fractures. Beitzel et al[5] biomechanically tested the stability of the single- and double-tunnel techniques and found no significant disparity.

The most serious issues observed after AC joint TightRope fixation have been postoperative redisplacement and implant failure.[22] A longer time from injury to surgery, tunnel malposition, incomplete initial reduction, and osteolysis are the possible factors for reduction failure.[22] Vulliet et al[36] described loss of reduction as upward elevation of the distal clavicle by >5 mm on radiographs. Çarkçı et al[8] declared the significant amount of displacement to be >3 mm. Zhang et al[40] stated that 25% of their patients had a significant loss of reduction that affected the functional scores. The exact complication of loss of reduction was detected by Özcafer et al[27] and Murena et al,[25] with no negative impact on the clinical outcome. Regarding this complication, we identified 1 patient (3.03%) who had partial displacement with a 3-mm side-to-side difference that did not influence function. A possible explanation for our finding is the shorter mean time elapsed before surgery compared with Zhang et al[40] (5.3 vs 12.9 days, respectively). Özcafer et al[27] reported 2 cases of implant failure due to coracoid tunnel malposition.

In terms of postoperative outcomes, the mean CM score was 93.3, and the mean UCLA score was 32.9 at the final follow-up. All patients had good to excellent results at the final follow-up visit. Similar results were noted by Özcafer et al,[27] who reported a mean CM score of 93.2, whereas Zhang et al[40] recorded a postoperative UCLA score of 30.5. Full overhead shoulder movement necessitates some micromotions of the AC joint. Studies concluded that rigid fixation of the AC joint was associated with limited overhead shoulder motions and unsuccessful functional outcomes.[24] The advantage of TightRope fixation is that it preserves the AC joint motions and maintains anatomic reduction.[24] At the end of the current study, the patients reached a mean shoulder elevation of 171.2°. Despite statistically inferior shoulder forward flexion compared with the unaffected side, all patients regained their preinjury overhead levels of activity, with no discernible clinical difference.

The CCD markedly diminished from 21.8 mm preoperatively to 10.6 mm postoperatively. Comparable postoperative measurements were documented by Fahmy et al[11] (10.2 mm), Olivos-Meza et al[26] (10.8 mm), and Zhang et al[40] (11.4 mm). Currently, there is no validated scale in the literature for CC ligament healing on MRI. As a result, we used a previously developed scale for anterior cruciate ligament (ACL) graft healing.[18] Ihara et al[18] established a classification scheme for MRI assessment of ACL graft healing. Faria et al[13] used the same scale to evaluate CC ligament healing in 10 patients who underwent open surgery that entailed two 5-mm anchors for fixation. Faria et al noted grade 2 healing scars in 5 patients, grade 3 in 3 patients, and grade 4 in 2 patients. Our patients achieved better MRI healing quality of the CC ligament. This finding was not investigated, but the closed surgical approach and CC fixation through the glenohumeral side without entering the subacromial space may be a reason. Additionally, the blood products of bone drilling that were brought into the closed CC space may provide a good biological environment for ligament healing. Some authors have found postoperative radiological calcifications in the CC space after arthroscopic fixation that had no effect on the clinical outcome.[38] This finding was not present in the current study.

Limitations

This was a retrospective study, which has all the limitations that come with such a design. The small number of included patients may recall selection bias. The duration of follow-up was so short that it was appropriate only for detecting early complications; the development of postoperative AC joint arthritis requires a longer period of follow-up. Also, the AC joint was not evaluated for pain after surgery using the cross-arm adduction test. There was no comparison group to evaluate alternative techniques. The functional assessment did not use a score evaluating the AC joint specifically, and the nature of healed ligament was not investigated. The scale used to assess the healing of the CC ligament on MRI was not validated. There were no records about the assessment of horizontal stability or radiographic calibration for CCD measurements. Furthermore, the interobserver reliability of the estimated CCD values was not tested. Finally, additional prospective studies for detailed measurements of the length, diameter, and angle of the healed ligament on MRI are strongly suggested.

CONCLUSION

At the completion of follow-up, the follow-up MRI displayed that the CC ligaments had healed well, with maintenance of radiographic stability. Moreover, arthroscopic TightRope fixation for acute AC joint lesions resulted in a satisfactory improvement in the functional outcomes as measured by the CM and UCLA scores. The patients resumed their preinjury activities and occupations.

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